The proposed Synergy waste processing and gasification/combustion system would take municipal solid waste (MSW), transform it through a series of highly controlled processes to a clean process biomass feedstock (PBF) similar in content and character to compost, gasify the PBF to produce a clean synthesis gas (syngas), then combust the syngas in a thermal oxidizer to produce renewable process heat energy. In addition to the necessary processing of the MSW to produce the PBF, the system also allows substantial diversion of recyclables from the waste stream. The gasifier produces a high-carbon biochar product that can be used in a variety of other environmental improvement applications including air and water treatment. The syngas created in the tightly controlled environment of the gasifier chamber provides the self-sustaining renewable heat energy (O2 starved) necessary for converting the PBF to the carbon rich renewable product. The residual waste gas is then routed to the thermal oxidizer to provide both the heat necessary for drying the feedstock to the optimized moisture content to reach the most efficient processing parameters while also acting as a pollution control step by combusting and scrubbing the flue gas prior to exiting the stack. Few systems extract such wide-ranging benefits from the waste stream, including a high-end use of the organic fraction, while limiting potential environmental impacts.

## Overview of MSW Processing Steps

The proposed system contains a number of steps intended to remove inorganics and convert the remaining organic MSW material (primarily paper, paper board, wood, and food) into the PBF material ideal for gasification. Materials rejected during the processing steps are recycled and/or disposed of if non-recyclable. Averages based on current operation of the processing system suggest that approximately 50-66% of the inbound MSW will be rejected and 33-50%, primarily high-grade organics, will ultimately be conveyed for gasification.

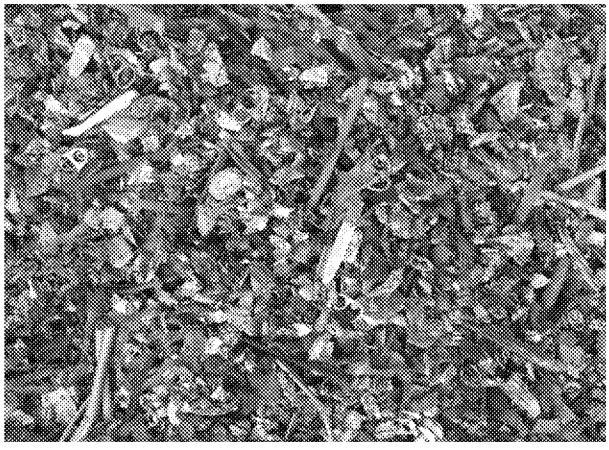
The process begins when incoming MSW is deposited on the tipping floor. An initial manual sort occurs to remove large and bulky items (primarily large metals) unsuitable for further processing, chemicals, or potential hazardous materials. These materials are removed and managed separately. The remaining waste is then transferred (by operator and machine) to a shredding and further screening operation to prepare a suitable waste stream for charging the BurCell® unit.

It is important to note that the BurCell® unit does significantly more than reduce the size of the material. The unit utilizes a combination of size reduction, rotary agitation, and heat/moisture/pressure control to batch-process the feedstock to improve further recycling of non-organic material and to break down and homogenize the remaining organic materials. The combination of heat and pressure also provides additional benefit of destroying some pathogens common to municipal waste stream management.

After treatment from the BurCell® unit, the material is sent through a 1" – 3/8" screening trommel and then onto second magnet station to remove any smaller ferrous metals that remain and then through a customized and enhanced eddy current system to remove non-ferrous particles down to two millimeters. Finally, the remaining material is further processed via a sweco machine and final third stage magnet to remove any minute metals remaining as well as slightly lighter pieces or microplastics or film particulates. The resulting highly processed fiber is conveyed to a charging hopper where it is staged for entry into the gasification system process. The first stage of the PBF into the gasifier system is entry to a drum dryer which is electronically controlled to optimize the moisture content (utilizing a tightly controlled portion of the waste syngas from the gasifier chamber to combust for process drying heat of the incoming PBF). The material exiting the drum dryer is moved through the pre-stack cyclone where it "scrubs" combusted flue syngas through the use of an upward draft fan. The exhaust gas is then exited through

the stack and the processed biomass feedstock (PBF) and is transferred through gravitational separation to a hopper where it is conveyed to the gasifier. The final PBF is homogeneous, primarily organic, similar in character to compost, and optimized with a large surface area for gasification. The PBF bears no resemblance to MSW.


Processed biomass fuel (PBF)


Smaller materials removed through processing

## Overview of Gasifier/Thermal Oxidizer

The Coaltec unit consists of a fixed bed gasifier which is coupled to a thermal oxidizer and associated appurtenances. Every process of the entire system is controlled by an Allen Bradley Programmable Logic Controller (PLC). Both the gasifier and the oxidizer have propane fueled burners utilized only during startup to heat ambient air to generate the heat necessary to dry the refractory slowly and to create a suitable environment for the self-sustaining gasification process to start. Once temperature is achieved, these burners are shut down and not used again until another startup is required.

A detailed process description is as follows:

1. When the unit is started, the gasifier is empty and contains no PBF. Both startup gas burners start at a low range (approximately 20%) and warm the refractory and then ramp-up to their maximum output.
2. The startup burners then continue at the maximum firing rate until a thermocouple in the upper section of the gasifier reaches 900°F.
3. At this point augers begin operating and PBF is introduced to the upper chamber of the gasifier unit and begins to react with the heat to produce syngas. As the PBF moves further into the reaction zone the temperature continues to increase. Once the temperature reaches 1,200°F. the startup burners are turned off because the ambient heat is no longer needed and the system becomes self-sustaining. The syngas is moved through natural convection and fan draft to the upper portion of the gasifier chamber where it reacts with the tightly controlled amount of air provided via the digital control system in the reaction zone of the gasifier well above the PBF bed on the floor of the unit. There is no combustion of the PBF in the gasifier. No flames ever come in contact with the PBF. The PBF is slowly augered through the processing zones where it chemically transforms to the carbon rich bio char product.

4. The reaction zone contains a single air pipe with multiple nozzles. A sub-stoichiometric amount of air is introduced into the reaction zone. The feed rate of PBF and volume of air introduced are both controlled through the system's automated process controls by Variable Frequency Drives.
5. The augers eventually move the material through a wall that prevents air from entering the reaction zone and then into a cooling zone.
6. The material is then pushed over another ledge and dropped onto the biochar auger that removes the biochar from the gasifier. Once it leaves the gasifier body a misting water spray is used to quench the biochar, eliminating potential for dust, aiding in the activation of the carbon and creating a water seal.
7. The syngas produced in the gasifier is predominately carbon monoxide (CO) and hydrogen with trace amounts of VOCs. Residual waste syngas not used for self-sustaining heat is pulled from the reaction zone through the upper section above the PBF and through a control damper in the roof of the gasifier.
8. Immediately downstream from the transition there is an air ring where air is added to convert the CO into $CO_2$ and the hydrogen to water vapor. The only combustion in the system occurs in the thermal oxidizer and the only fuel combusted is the clean syngas. The PBF material is in a completely separate chamber and is never in common proximity of the combustion zone.
9. The oxidizer is designed to contain the flame from the syngas combustion and produce a hot flue gas stream at 1,600 to 1,800°F.
10. The hot flue gas is temperature controlled and routed directly through the drum dryer, into a cyclone for removal of particulate matter, and then is emitted to the atmosphere through the unit stack.

Because the Coaltec unit was designed to run only clean organic PBF, it utilizes a thermal oxidizer that is close-coupled to the gasifier for maximum efficiency. To reiterate, unlike other systems that gasify or pyrolyze minimally processed MSW and produce syngas and char with a presumed higher level of contaminants, the Synergy system provides for extensive processing of the MSW that removes contaminants such as metals and chlorinated plastics *prior* to gasification, resulting in the production of a cleaner syngas and biochar relative to syngas produced from unprocessed MSW.